Aerogels for Thermal Insulation

Highly efficient, lightweight, and transparent insulating materials

Aerogels are the best thermal insulators available today. Two organic aerogels developed at LLNL have equivalent R values of 12 when air-filled (equivalent to the insulating capacity of 6 in. of fiberglass batting) and greater than 38 when evacuated (equivalent to 19 in. of fiberglass).

Unique structure means superior insulation

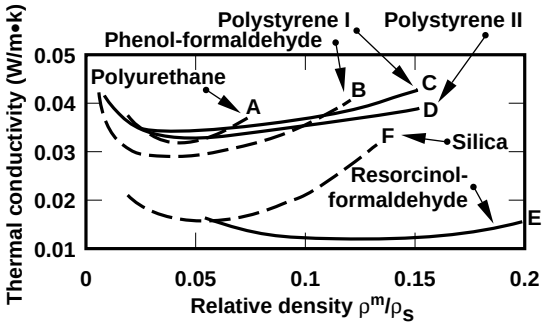
The unique microstructure of aerogels—nanometer-sized cells, pores, and particles—means low thermal conduction.

Thermal conduction through the solid portion of the aerogel is limited by the small connections between the particles making up the conduction path. Gaseous conduction is limited because the cells/pores are only the size of the mean-free path for molecular collisions—molecules collide with the solid network as frequently as they collide with each other. Radiative conduction is low because aerogels have small mass fractions and large surface areas—although conductivity increases with temperature.

Measurable, low thermal conductivities

- Silica aerogels at 300 K and 1 atm have measured conductivities as low as 0.020 W/m·K (an R per inch value of about 7).
- Organic aerogels have thermal conductivities of 0.012 W/m·K (an R per inch value of 12).
- Carbon particle–loaded (opacified) silica aerogels have thermal conductivities of 0.013 W/m·K (an R per inch value of 11).

Organic aerogel materials have lower intrinsic thermal conductivity than silica and up to a factor of 4 higher infrared extinction coefficient than unmodified silica aerogel. Adding carbon particles to the silica aerogel decreases the dependence of the thermal conductivity on temperature. The dependence of thermal conductivity on density shows that conductivity is minimum at an optimal density, typically about 0.1 g/cm^3.



Lightweight aerogels are much better insulators than common foams.

Tailored aerogel properties

Aerogels provide thermal resistance per inch almost twice that of commonly used polyurethane foams. Silica aerogels are also nonflammable, nontoxic, lightweight, transparent, and thermally stable to about 650°C.

Because mechanical properties vary with density, composition, and processing conditions, we can tailor the optimal aerogel composition for a desired thermal conductivity. Modest evacuation of the aerogel (about 0.05 atm), for example, results in lower thermal conductivities: our lowest measured value is about 0.004 W/m·K. Preliminary laboratory data and theory suggest that by controlling the microstructure, we can achieve R values of 20 or greater for 1-in., air-filled aerogels at 1 atm and room temperature.

Availability: Aerogels are available now. We are seeking industrial partners with whom we can develop new aerogel materials or optimize existing aerogels for specific applications.

APPLICATIONS

- *Thermal insulation in rockets and satellites*
- *Cryogenic insulation*
- *Fire-retardant packing materials*
- *Thermal insulators for temperature-sensitive products, insulative clothing, and improved energy efficiency*
- *Insulation for glass products: window glass, solar collectors and covers, refrigerators, water heaters, and electronic components*

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